Source Apportionment of air pollution in the Danube region

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Danube Air Nexus

WP 1: **Identifying air pollution sources** (leader: C. Belis)

Source apportionment models will be applied to measurements from selected areas of the region to quantify the contribution of sources to air pollution.

WP 2: **Scenarios for emissions and future air quality** (leader: M. Muntean)

Scenario analysis about the impacts of pollutants on human health, air quality and agriculture, including the effect of modal shift will be performed.

WP 3: **Climate change scenarios for the Danube Region** (leader A. Dosio)

Bias-corrected scenarios for Climate Change, focused on the risk of extreme events (drought, heat waves, heavy rain,…) will be made available.

WP 4: **Assessing impacts on PAH on health** (leader L. Gribaldo)

The impact of atmospheric carcinogenic/genotoxic Polycyclic aromatic hydrocarbons (PAHs) on child development will be assessed.
Outline of the presentation

What is source apportionment?
Why is it important to identify pollution source contributions?
What are the most commonly used methods for SA?
What are the most common sources of PM in Europe?
Examples of SA studies
Case study 1  Po Valley and Southern Alps
Case study 2  Southern Poland
What is source apportionment?

**Source Apportionment (SA)** is the practice of deriving information about pollution sources and the amount they emit from ambient air pollution data.

Why is important to accomplish source apportionment?

To quantify the contribution of sources at the point where the population is exposed
To support the development of abatement measures
To test the efficacy of air quality plans
What do AQ Directives say about pollution sources?

Reduction of emissions at source (Preamble point 16)

One of the overarching principles of the Thematic Strategy on Air Pollution.

Local, regional and national air quality plans (Annex XV A item 5)

Emitted quantities and transboundary sources responsible for pollution are to be listed when drafting air quality plans.

Background measurements (Annex IV A)

To judge the enhanced levels in more polluted areas, assess long-range transport, support source apportionment analysis and understanding of specific pollutants.

Ozone precursors (Annex X A)

Measurements to monitor the efficiency of emission reduction strategies, to check the consistency of emission inventories and to help attribute emission sources.

Natural sources, road salting and sanding (Articles 20 and 21)

To provide evidence of exceedances attributable to natural sources or winter sanding or salting of roads.

Public information (Annex XVI item 4)

Information about exceedances of alert thresholds including indication of main source categories and recommendations for action to reduce emissions.
BIOMASS BURNING AND DOMESTIC HEATING

AGRICULTURE

INDUSTRY AND POWER GENERATION

VEHICLES

NATURAL

ATMOSPHERIC CHEMISTRY

DUST RESUSPENSION

SEA SALT

BIOGENIC EMISSIONS
Emissions of atmospheric pollutants

1. SOURCES
2. PHYSICAL AND CHEMICAL PROCESSES
3. METEOROLOGY
4. TO THE ATMOSPHERE
5. CONCENTRATIONS AT THE RECEPTOR
Source estimation methods

1. EMISSION INVENTORIES

2. CHEMICAL TRANSPORT MODELS
   DISPERSION MODELS

3. RECEPTOR MODELS
   INVERSE MODELS

TO THE ATMOSPHERE

PHYSICAL AND CHEMICAL PROCESSES

CONCENTRATIONS AT THE RECEPTOR

METEOROLOGY
1. EMISSION INVENTORIES

- Required for reporting obligations
- Do not consider atmospheric processes
- Official data could be sketchy/inconsistent

2. CHEMICAL TRANSPORT MODELS

- Consder atmospheric processes
- Provide high resolution spatial and temporal estimations
- Intensive computing resources and good parametrization needed
- Simulation for short time windows
- Output depends on input data quality

3. RECEPTOR MODELS

- Derive directly from data collected at the point of interest
- Have good uncertainty estimation
- Require field work and chemical analyses
- Not applicable to all pollutants
Sources of particulate matter (PM) in Europe
Sources of Particulate Matter in Urban Areas in Europe

- Sea/road salt, 5%
- Secondary inorganic, 33%
- Crustal, 17%
- Traffic, 19%
- Biomass - wood burning, 14%
- Point sources, 15%

272 records, meta-analysis of studies carried out between 1998 and 2012. Source: Belis et al., 2013 Atmospheric Environment 59
Biomass burning and PM
Average emission factors for different technologies and fuel type (source: Caserini et al., 2006)

<table>
<thead>
<tr>
<th>fuel</th>
<th>SO2</th>
<th>NOX</th>
<th>CO</th>
<th>NMVOC</th>
<th>PM10</th>
<th>PAH</th>
<th>PCCD/F</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler &lt;50 MW natural gas</td>
<td>0,5</td>
<td>50</td>
<td>25</td>
<td>5</td>
<td>0,2</td>
<td>n.d.</td>
<td>2</td>
<td>222.291</td>
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<tr>
<td>Boiler &lt;50 MW gas oil</td>
<td>100</td>
<td>50</td>
<td>20</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>28.135</td>
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<tr>
<td>Boiler &lt;50 MW fuel oil</td>
<td>150</td>
<td>150</td>
<td>16</td>
<td>10</td>
<td>40</td>
<td>5</td>
<td>10</td>
<td>1.296</td>
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<tr>
<td>Open fireplace wood</td>
<td>13</td>
<td>70</td>
<td>5650</td>
<td>5650</td>
<td>500</td>
<td>280</td>
<td>170</td>
<td>3.672</td>
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<tr>
<td>Stove traditional or closed</td>
<td>wood</td>
<td>13</td>
<td>70</td>
<td>5650</td>
<td>1130</td>
<td>250</td>
<td>280</td>
<td>170</td>
</tr>
<tr>
<td>Stove innovative wood</td>
<td>13</td>
<td>60</td>
<td>2260</td>
<td>560</td>
<td>150</td>
<td>280</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Wood BAT or stove pellets</td>
<td>wood</td>
<td>13</td>
<td>70</td>
<td>1130</td>
<td>110</td>
<td>70</td>
<td>0,3</td>
<td>n.d.</td>
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<tr>
<td>BAT pellets</td>
<td>wood</td>
<td>13</td>
<td>60</td>
<td>620</td>
<td>60</td>
<td>30</td>
<td>0,1</td>
<td>n.d.</td>
</tr>
</tbody>
</table>

Significant differences between wood and other fuels and among wood combustion technologies
Wood and pellet burning profiles

Closed fireplace pine wood

- EC: 33.9%
- OC: 54.8%
- Sulfate: 5.9%
- Others: 1.5%

Pellet (Spruce) fueled stove

- OC: 61.3%
- Sulfate: 9.5%
- Trace elements: 25.3%
- K, S, Ca, Zn: 1.6%

Colombi et al., 2010
Contribution of biomass burning to PM$_{10}$ and PM$_{2.5}$ in Europe

- Studies (n=89) started in the past decade due to the concern about the potential impact of domestic wood burning and open fires on PM.
- Levoglucosan and Potassium are tracers for this source.
- There is a high variability in the emission factors due to the wide range of fuels and appliances used for combustion.
- In Europe, the median relative contribution of biomass burning to PM is 14% [PM$_{2.5}$ (15%), PM$_{10}$ (12%)].
- Contributions are higher during the cold season.
- The highest relative contributions were observed in the Alps and in Northern Europe.
Case study 1: Source apportionment in the Po Valley and Southern Alps
Source apportionment in Po Valley and Southern Alps

- Ten monitoring sites
- Two winter campaigns: 2007 and 2009
- Multi species analysis of PM$_{10}$ and PM$_{2.5}$
- 32,376 data points

Larsen et al., 2012
Source apportionment in Po Plain and S. Alps

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Kerbside</td>
<td>94</td>
<td>99</td>
<td>8</td>
<td>12</td>
<td>33</td>
<td>30</td>
<td>5</td>
<td>5</td>
<td>29</td>
<td>51</td>
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<tr>
<td>Urban background</td>
<td>83</td>
<td>75</td>
<td>12</td>
<td>13</td>
<td>29</td>
<td>18</td>
<td>15</td>
<td>12</td>
<td>43</td>
<td>57</td>
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<tr>
<td>Regional background</td>
<td>66</td>
<td>52</td>
<td>7</td>
<td>11</td>
<td>14</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>50</td>
<td>47</td>
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<tr>
<td>Residential area</td>
<td>71</td>
<td>86</td>
<td>16</td>
<td>16</td>
<td>30</td>
<td>16</td>
<td>7</td>
<td>7</td>
<td>30</td>
<td>45</td>
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<tr>
<td>Po Plain stations</td>
<td>71</td>
<td>86</td>
<td>10</td>
<td>12</td>
<td>17</td>
<td>16</td>
<td>11</td>
<td>10</td>
<td>36</td>
<td>49</td>
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<tr>
<td>Valtelline Valley</td>
<td>48</td>
<td>50</td>
<td>31</td>
<td>31</td>
<td>30</td>
<td>32</td>
<td>8</td>
<td>4</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Urban background Summer/autumn</td>
<td>58</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>49</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>46</td>
<td>-</td>
</tr>
<tr>
<td>SIA %</td>
<td>29</td>
<td>51</td>
<td>22</td>
<td>23</td>
<td>43</td>
<td>57</td>
<td>21</td>
<td>23</td>
<td>50</td>
<td>47</td>
</tr>
<tr>
<td>SOA %</td>
<td>22</td>
<td>23</td>
<td>23</td>
<td>21</td>
<td>23</td>
<td>23</td>
<td>19</td>
<td>15</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

Relative SCEs for PM-sources in the Po Plain divided into five categories of sites. The data are expressed as median values.
Source apportionment of PM in Po Valley and Southern Alps

• BB is the third most important source during winter.

• BB median contributions for all Po Plain stations is 10% to the PM$_{10}$ mass (2007) and 12% to the PM$_{2.5}$ mass (2009).

• The absolute SCEs for the site categories (medians) varied from 5 to 12 μg/m$^{-3}$ and were highest at the residential area. This fact, together with the much lower SCEs measured during a summer/autumn campaign support the assumption that BB derives mainly from residential heating.

• In the Valtelline Valley higher median contributions from BB were revealed (15 μg/m$^{-3}$ corresponding to 31% of the mass)
## Source contribution estimations for Benzo(a)pyrene in Po Valley and Southern Alps

<table>
<thead>
<tr>
<th>SITE TYPE</th>
<th>CONTR. OF BB TO BaP (ng/m³) 95% CI</th>
<th>CONTR. OF BB TO BaP (%) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>KERBSIDE</td>
<td>1.0 ± 0.4</td>
<td>74 ± 32</td>
</tr>
<tr>
<td>URBAN BKG</td>
<td>1.0 ± 0.2</td>
<td>79 ± 18</td>
</tr>
<tr>
<td>RURAL BKG</td>
<td>0.7 ± 0.3</td>
<td>85 ± 33</td>
</tr>
<tr>
<td>URBAN BKG ALP</td>
<td>2.1 ± 1.1</td>
<td>84 ± 46</td>
</tr>
</tbody>
</table>

### Po Valley

### Alpine Area

**Uncertainty for emission factors (mg/g PM) 69% levo/PM and 68% (BaP/levo)**

Source: Belis et al., 2011 Atmospheric Environment 45: 7266-7275
Source apportionment of Benzo(a)pyrene in Po Valley and Southern Alps

- Receptor models with a large set of predictor compounds can produce estimates of the contributions from biomass burning to particle-bound benzo(a)pyrene with uncertainties in the order of 20-50%.
- Biomass burning contributes with more than 75% of the benzo(a)pyrene pollution in the cities of the Po Plain during winter.
- The highest benzo(a)pyrene concentrations were encountered in Sondrio (urban background) where Target values for this pollutant are often exceeded.
- PMF simulations demonstrated, that the drawn conclusions for benzo(a)pyrene can be extended to the sum of 4-6 ring PAHs.
Case study 2: Source apportionment in Southern Poland
Source apportionment in Southern Poland

Source contribution estimates (±95% confidence interval) for PM$_{10}$ (µg/m$^3$)

<table>
<thead>
<tr>
<th>Source category</th>
<th>comments</th>
<th>Krakow</th>
<th>Zakopane</th>
</tr>
</thead>
<tbody>
<tr>
<td>House heating</td>
<td>residential coal combustion in small stoves and boilers</td>
<td>11±5</td>
<td>16±16</td>
</tr>
<tr>
<td></td>
<td>residential heating (wood, coke, oil)</td>
<td>13±6</td>
<td>58±31</td>
</tr>
<tr>
<td>Industrial power generation</td>
<td>low-efficiency boilers (coal)</td>
<td>17±3</td>
<td>5.5±4.4</td>
</tr>
<tr>
<td></td>
<td>high-efficiency coal combustion</td>
<td>13±5</td>
<td>1.1±0.9</td>
</tr>
<tr>
<td>Secondary inorganic aerosol</td>
<td>ammonium nitrate and sulphate, chlorides</td>
<td>16±2</td>
<td>9.4±4.4</td>
</tr>
<tr>
<td>Traffic</td>
<td>exhaust</td>
<td>3.7±1.5</td>
<td>0.5±0.4</td>
</tr>
<tr>
<td></td>
<td>resuspension (including road salt)</td>
<td>2.0±0.3</td>
<td>0.2±0.4</td>
</tr>
</tbody>
</table>

Source contribution estimates (±95% confidence interval) for toxic pollutants in PM$_{10}$ (ng/m$^3$) all sites average

<table>
<thead>
<tr>
<th>Source category</th>
<th>Benzo(a)pyrene</th>
<th>Pb</th>
<th>Cd</th>
<th>Ni</th>
<th>As</th>
</tr>
</thead>
<tbody>
<tr>
<td>House heating (mainly coal)</td>
<td>28 ± 4</td>
<td>17±2</td>
<td>0.3±0.04</td>
<td>0.2±0.03</td>
<td>0.2±0.03</td>
</tr>
<tr>
<td>LE-boilers (coal)</td>
<td>3.4±0.4</td>
<td>43±5</td>
<td>1.3±0.1</td>
<td>0.8±0.1</td>
<td>0.9±0.1</td>
</tr>
<tr>
<td>HE-coal combustion</td>
<td>1.9±0.4</td>
<td>25±5</td>
<td>0.8±0.2</td>
<td>1.1±0.2</td>
<td>not sign.</td>
</tr>
<tr>
<td>traffic and resuspension</td>
<td>0.04±0.01</td>
<td>5.6±1.0</td>
<td>not sign.</td>
<td>0.3±0.1</td>
<td>not sign.</td>
</tr>
</tbody>
</table>

Junninen et al., 2009 EST 43: 7964-7970
Source apportionment of PM and benzo(a)pyrene in Southern Poland

- The highest primary contributions to the PM$_{10}$ pollution in Krakow (30-50%) derive from home heating mainly associated with coal combustion
- In Zakopane, this source contributes 80-90% of PM$_{10}$ and is associated with both coal and wood combustion
- In Krakow, almost the totality of benzo(a)pyrene is attributed to coal combustion.
Impact of Small Combustion to PM in the Danube area

Small Combustion: Stationary commercial/ institutional/ residential/ agriculture/ forestry/ fishing

Emissions from Small Combustion

Differences could be due to: type of fuel, and/or combustion technology or differences between countries in the methodologies to estimate emissions

Source apportionment studies are expected to contribute to improve the estimations by quantifying the contribution from different fuels

Data source CEIP-EMEP, officially reported emission data EU 28 year 2012
Thank you for your attention